Design of Childproof Barriers to Prevent Falls from a Height in Public Places

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Abstract. This paper highlights the risk of children falling from a height in public places. Injury statistics and points of law are noted and examples of poor design are given. Good design features are discussed. It is stressed that conformance with building standards should be followed by regular assessment of public safety issues and action as appropriate.

INTRODUCTION

This paper addresses design aspects in relation to barriers needed to prevent falls of children. Falls are one of the highest causes of injury among children. In Australia (exluding the Northern Territory) in 1992-1993 falls caused 6642 hospitalizations of children aged 0-4[1]. This represented 33% of the total for this age group and was the highest category. Fatalities from falls are not as common as from hazards such as drowning or motor vehicle accidents[2,3,4,5], however fatal falls are not insignificant. Over the twenty years between 1979-1998, 88 children in Australia aged 0-4 years were fatally injured by a fall[6]. The potential for serious injury is greater as the height increases[7], however the number of injuries from low-height falls is much greater[8], presumably due to much greater exposure to this type of danger and perhaps because of poorer precautions. Injuries from falls, even from very low heights, can be serious and it has been shown that 40 percent of fatal falls among children under 15 were from less than 3 feet[9]. It is clear that falls, even from low heights, have the potential to cause serious, and sometimes fatal, injuries[10].

The duty of care owed to the public in public buildings in Australia has been described in *Australian Safeway Stores v Zaluzna*[11]. In this case the plaintiff was injured when slipping on a wet floor inside a supermarket. In regard to the danger that children would face in public areas, there will be a duty on those who exert control over the facilities to identify fall hazards and put reasonable protections in place.

Recently in the case of *Toomey v Scolaro's Concrete Constructions Pty Ltd (in liq) & Ors* an adult was awarded damages in excess of $2M after suffering severe spinal injuries following a fall from a balcony. A key aspect was the construction of a balcony railing built at a height too long to provide reasonable protection against a fall (933.5mm).

In the case of *Pollock v Robinson & Russell*[12] a toddler fell through a barrier on a balcony. The barrier consisted of vertical bars. The spaces between the vertical bars were generally about 125mm but at the point where the toddler fell through the spaces were 155mm[13]. Severe injuries were suffered that had serious effects for many years. Judgement in excess of $700,000 was awarded.

In many public places and in publicly accessible buildings, it would seem foreseeable that a child might attempt to climb or pass through a barrier placed at the edge of a balcony or other place where a fall is possible. The propensity of children to climb and pass through inappropriately-designed barriers has been identified and reported as a hazard since at least 1972[14] and many times since[15,16,17,18]. For instance:

"The spaces between balusters and the openings in ornamental railings can present a hazardous invitation to children at play. The normal inquisitive child will put his hands, feet, and head into openings which appear to be large enough to accommodate them, often with painfully disastrous results."[19]

It is therefore a task of balancing the magnitude of the risk against the cost and inconvenience of putting preventative measures in place[20]. In the case of children climbing, passing through or becoming trapped in a barrier, the probability would depend highly on the circumstances but the key point is that the solution is relatively simple. At the design stage, the cost of a childproof barrier would be basically the same as many dangerous barriers. Where unsafe barriers are in place then there would be costs to bring a barrier up to standard. The features of a good barrier are discussed as follows.

CHILDPROOF BARRIERS

There are a number of important points in the design of barriers and among these are that:

1. the barrier be non-climbable; and
2. where bars are used (e.g. vertical bars used to fulfil point 1.) that they are spaced in such a way as to prevent both complete passage and entrapment of a child.

"Toddlers, often avid climbers busy exploring their world without the aid of experience, are particularly prone to fall from heights because their climbing ability is not matched by balancing or reasoning ability. Their small bodies can slip between widely spaced guardrail uprights, sometimes trapping the head, or their climbing abilities may allow them to fall over the top if they can gain a foothold."[21]

There are other considerations that are important but not discussed here including: barrier height; barrier strength and durability; and elimination of sharp points and edges. This paper is limited to the discussion of the need to provide a non-climbable and non-accessible barrier as it is these features that seem to be poor in many cases.

Firstly, it is widely recognized that barriers should be non climbable[22,23]. This can be achieved by using vertical bars or solid panels such as concrete or glass. Where vertical bars are used, the supporting horizontal elements must be positioned carefully to avoid creating a climbing hazard. The current swimming pool standard prohibits horizontal elements between 100mm and 1000mm[24] and the *Building Code of Australia*[25] prohibits these between 150mm and 760mm.

SPACING OF VERTICAL BARS

Where vertical bars are used, or there are gaps in a sheet-like barrier, then it is crucial that these gaps are small enough to prevent a child passing through or becoming trapped in the barrier. In the case of *Pollock v Robinson & Russell* [26] vertical bars were used with a gap at one point of 155mm. The danger of the construction of the barrier seemed to rest simply on the fact that a child had fallen through and it was therefore self-evident that the barrier was unsafe. Following this we could say that a 155mm gap is too great. However, what is the safe spacing?

Table 1 shows recommendations for various situations. Recommendations for cots and playpens are reasonably consistent and tend to be smaller owing to their use by very young children. Recommendations for other situations are less consistent and cover a wide range from 70mm to 125mm. The US Consumer Product Safety Commission offered the following explanation for spacing at the lower end of this range:

"A child's head may become entrapped if the child enters and opening either feet first or head fist… Head entrapment by head-first entry generally occurs when children place their heads through an opening in one orientation, turn their heads to a different orientation, then are unable to withdraw from the opening. Head entrapment by feet-first entry involves children who generally sit or lie down and slide their feet into an opening that is large enough to permit passage of their bodies but is not large enough to permit passage of their heads. Generally, an opening presents an entrapment hazard if the distance between any interior opposing surfaces is greater than 3.5 inches and less than 9 inches." [27]

In short, designers would be well advised to adopt a spacing between 70 and 85mm for all barriers.

Table 1: Recommended Spacing for Vertical Bars in Barriers from Various Sources

Balconies, etc	Playgrounds, pools, etc	Cots & playpens
127mm (5") max[28,29]	125mm max[30]	75-100mm[31]
125mm max[32]	100mm max[33, 34]	50-95mm[35,36]
100mm max[37,38]	89mm (3.5") max[39]	60-85mm[40]
90mm max[41]		
80mm max[42]		
70mm[43]		

EXAMPLES OF THE PROBLEM

1. Climbing hazard

Figures 1-3 show a range of barriers. Each are constructed of horizontal rails that would prove climbable for small children. Adjacent to each are examples of non-climbable barriers made either of concrete or vertical bars.

Figure 1: Climbable barrier with adjacent non-climbable barrier
Figure 2: Climbable barrier with adjacent non-climbable barrier
Figure 3: Climbable barrier with adjacent non-climbable barrier

Some of the structures shown are many years old however relatively new structures are not necessarily better. Figures 4 and 5 show the barrier alongside the concourse around a recently constructed sports stadium (Colonial Stadium in Melbourne) that is several metres above the area below. Non-climbable barriers constructed of concrete are used for much of the length and perhaps the steel barriers were put in place as architectural features to break up what would be an otherwise long and continuous concrete wall. However, there are ample safe alternatives, such as perforated steel, glass and steel mesh, as used on a nearby pedestrian bridge (Figure 6).

Figure 4: Climbable barrier
Figure 5: Climbable barrier
Figure 6: Non-climbable barriers

2. Climbing and access hazard

Figure 7 shows a barrier along a stairway outside the Melbourne Cricket Ground (MCG). The potential fall is again several meters on to a hard surface. Unfortunately, the three-rail barrier is both climbable and the spaces are too large at about 200mm. Figure 8 another stairway outside the stadium. The interesting factor here is that in the landing areas, better protection has been provided (using a mesh in-fill). The justification might be that congregation is more likely on the landings, but the small cost saving is hard to follow. Nearby, on the bridge from the MCG to the Tennis Centre, the barrier is a much better design (Figure 9).

Figure 7: Rail barrier with overly large gaps
Figure 8: Rail barrier with overly large gaps
Figure 9: Barrier with no gaps

3. Climbing, access and entanglement hazard

Figure 10 shows a cable barrier along the edge of a balcony. These types of barriers are hazardous because they are climbable. In addition, because the cables are flexible, the spacing can be pushed out to a greater size allowing a child can squeeze through. The cables also present an entanglement and choking hazard and because of their small diameter are also much sharper than larger diameter bars.

Figure 10: Cable barrier

4. Access hazard

Figure 11 shows a barrier on a footbridge that is well-designed in that it prevents climbing, however the spacing of the bars is too great at 190mm. In addition at the left-hand end of the bridge one of the bars is bent. Even if the spacing was well-designed, the safety of the barrier depends on that spacing remaining appropriate throughout the structure's life. Barriers must therefore be robust and allow for construction error and damage over time.

Figure 11: Access hazard - gaps too great

CONCLUSION

1. A mistaken reliance on regulations

Many people may believe that compliance with building regulations will assure safety of the structure and its users. Indeed non-compliance with a regulation should sound a warning bell that safety may be compromised, but the reverse is not necessarily true and the following problems are evident:

1. While the current *Building Code* requirements[44] are a considerable improvement over the design of many barriers that we can see around Melbourne, they are not as stringent as other literature would advise. This is especially the case with regard to the size of gaps in the barrier.

2. Because compliance with the *Building Code* is mandatory, some people may have the impression that all legal requirements are satisfied. The common law duty of care may however not be met. With regard to common law, the *Building Code* would certainly be a good indicator of the state of knowledge about safe building design, but it would not the only indicator. Other standards and guidelines such as those noted in this paper would be relevant in determining the state of knowledge about good practice.

3. Over the years the *Building Code* requirements have changed and surely will change again. Structures built under less-demanding minimum requirements may not necessarily be "safe". This highlights the need for building safety to be the subject of periodic review. Rectification should be performed, taking into account the potential danger, the current state of knowledge about good barrier design, and the practicalities of doing so bearing in mind the cost and inconvenience. The fact that a barrier complied at the time of construction with a now-superceded minimum building requirement is not a convincing argument against making improvements later if they are feasible.

2. Focus on safety

Those operating public spaces need to be aware of their duties in relation to all potential users, including children. Obviously children will be present in places like schools, child-care centers and shopping centers and design for children should be a clear requirement. However, in other public places, it is foreseeable that children will be present. This includes many workplaces, entertainment areas, sports areas, libraries, universities, hotels, etc. Falls are among the highest causes of injury and a proportion of these injuries are fatal. In many public areas barriers are needed to prevent falls. Usually these provide adequate protection for adults, however the protection provided for children is often very poor. The two most evident problems are that barriers are climbable and that the spacing of bars is often too great. These barriers may offer some protection, but in another sense they might offer a false sense of security. A carer may well have a young child at their feet and be unaware of the potential danger that exists.

Compliance with the current *Building Code of Australia* would see better barriers included on new structures, although some more stringent requirements would be advisable. It should be stressed that at the design stage, a good barrier differs mainly in thought and care rather than cost. For instance there is arguably little difference in the cost of a vertical-bar or in-fill barrier and a horizontal-bar barrier. Diversity in style is welcome but the standards of protection should be maintained and a great variety of safe barriers can be devised. Those managing existing facilities need to undertake a review of fall hazards. These audits should identify barriers that are unlikely to perform their required function in particular in relation to climbability and accessible gaps. These audits should broadly consider foreseeable users such as children even if they may be infrequent visitors. Following these audits, action should be taken, given considerations of cost and inconvenience, to upgrade these barriers to a safe standard.

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